Limits on Primordial Gas in the AU Microscopii Disk from Far-UV Spectroscopy

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Introduction

- AU Mic : M1 star member of Beta Pic Assoc.
  - 12 Myr old (Zuckerman et al. 2001)
- Recently imaged edge-on disk
  - Ground-based (Kalas, Liu, & Matthews 2004)
  - HST-ACS (Krist et al., this meeting)
- Lifetime of dust outside 50 AU >> age of star
  - Weak radiation pressure (Kalas, Liu, & Matthews 2004)
- Does primordial material survive?

  Do stellar phenomena control disk dissipation?

Molecular Gas in AU Mic

- Primordial H_2 needed for giant planet formation
- Sub-mm observations : (Liu et al. 2004)
  - Dust mass = 0.011 $M_\oplus$
  - $N_{CO} < 6.3 \times 10^{13}$ cm^{-2}
  - Using assumed CO/H_2 ratio, mass of $H_2 < 1.3$ $M_\oplus$
  - Gas-to-dust ratio < 118 : 1
  - ISM ratio = 100 : 1
- Consistent w/ no gas depletion relative to dust
  - FUSE H_2 limit in Beta Pic : primordial gas depleted (Lecavelier des Etangs et al. 2001)

Why UV?

- Far-UV transitions of H_2 very strong
- Sensitive to cold gas
  - J=0,1 contain > 90% of molecules at T < 200 K
- No CO/H_2 ratio needed
- But M-star far-UV continuum very weak
- H_2 lines overlap with emission lines

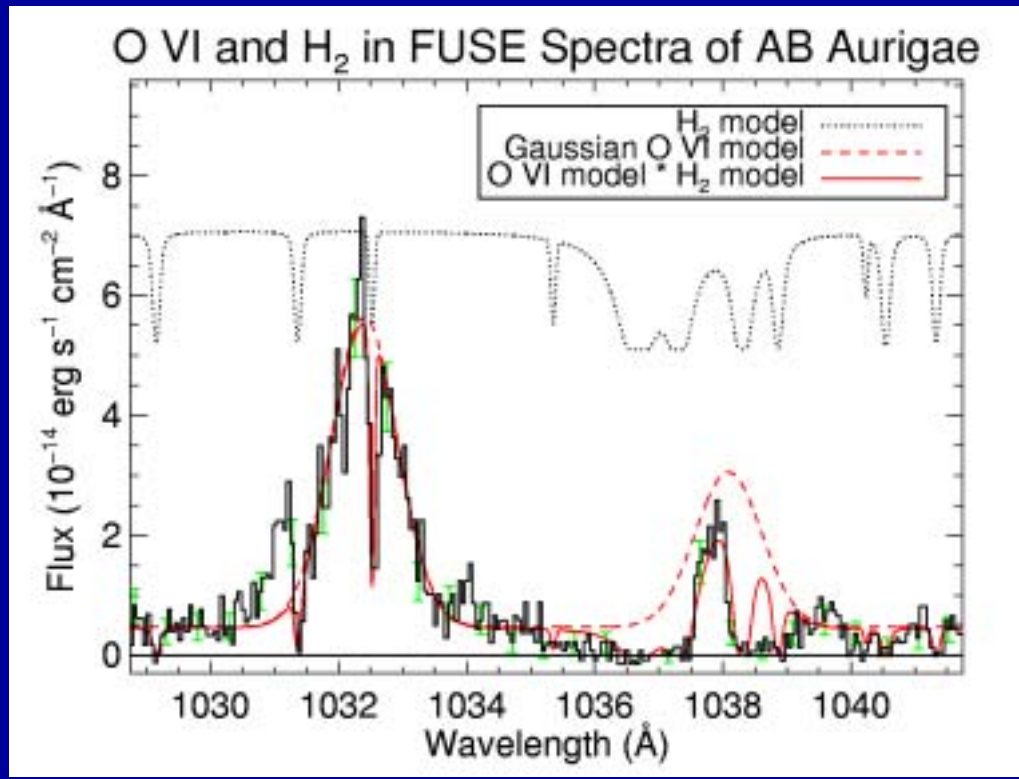


Figure 2a, Roberge et al. (2001)

Can provide background flux for H_2 absorption spectroscopy

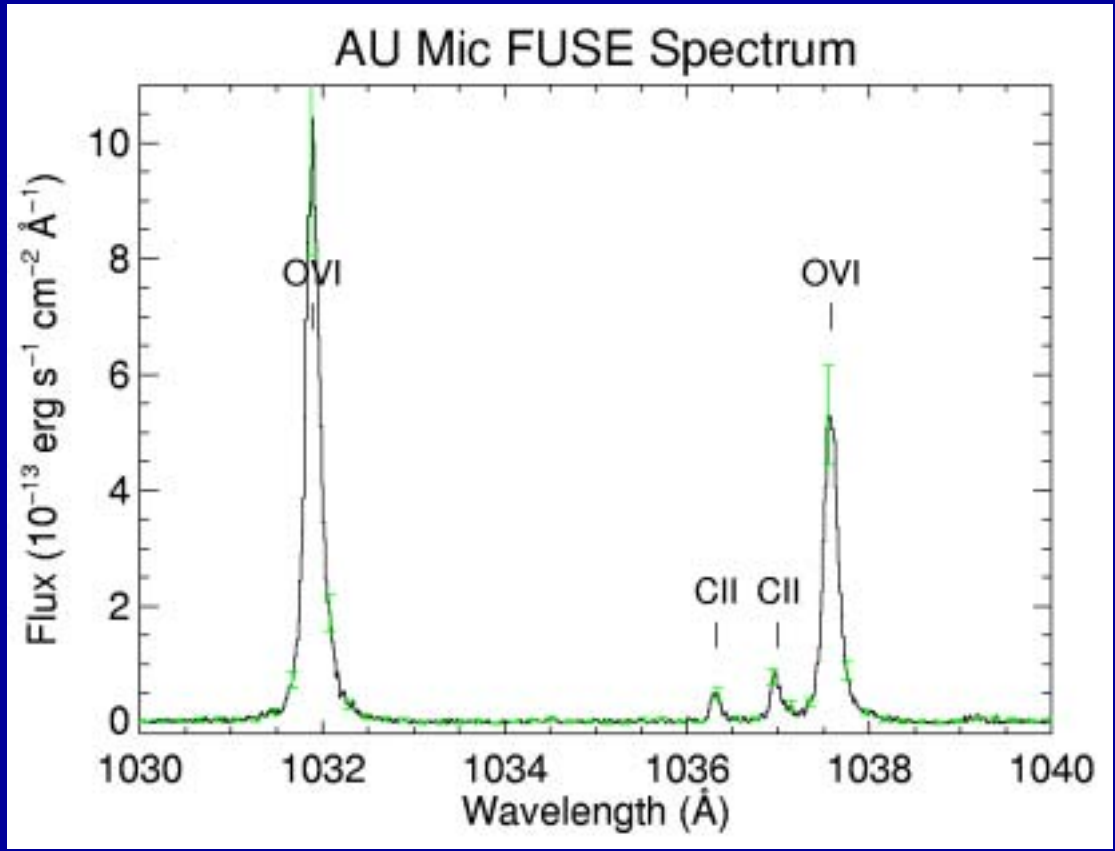
Data Reduction

	Observation Date
FUSE	2000 Aug 26 (Redfield et al. 2002) 2001 Oct 10
STIS	1998 Sept 6 (Pagano et al. 2000)

- Recalibrated all data
- Excluded exposures containing flares
- Set FUSE absolute wavelength calibration

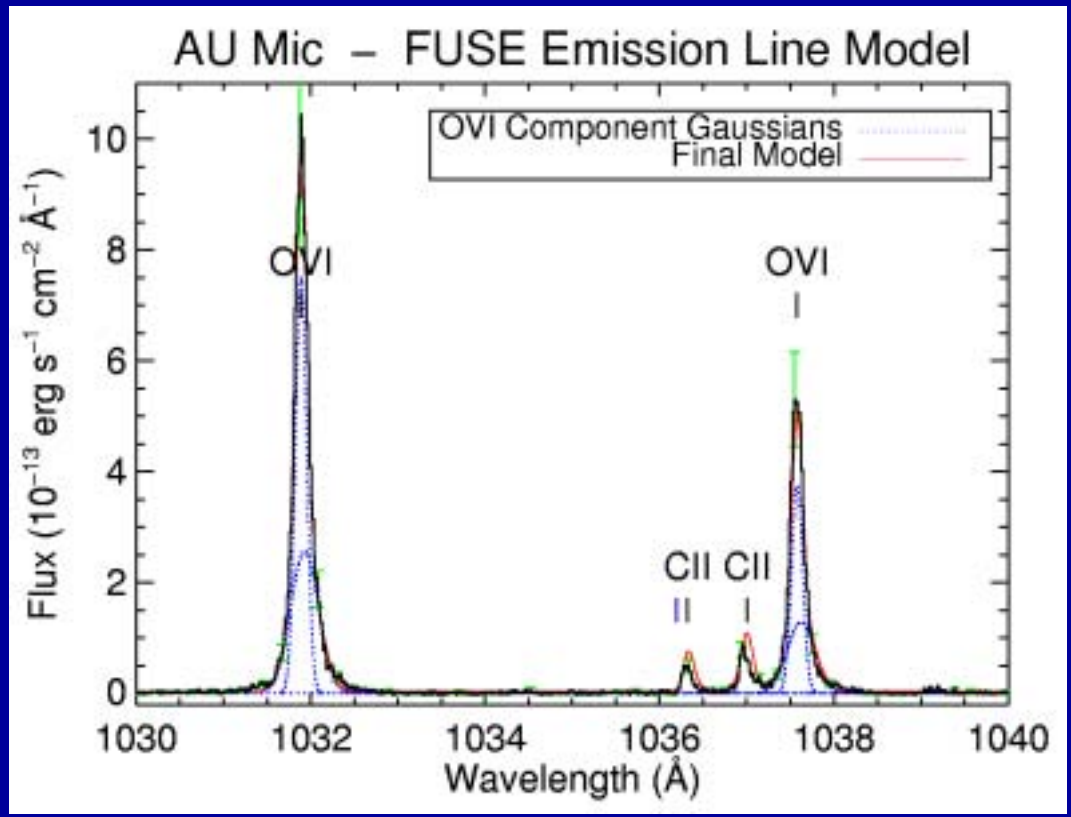
FUSE Emission Lines

- Transition zone OVI lines, chromospheric CII lines
- Measured OVI flux ratio ≈ 2:1
- Means little H_2 absorption
- CII lines provide tighter constraint



Model for FUSE Emission Lines

- CII doublet model :
  - Used STIS CII λ1335 parameters
  - Added interstellar CII absorption
  - Convolved to FUSE resolution
- OVI doublet model :
  - Fit two Gaussians to λ1032 line
  - Model λ1038 line (1:2)



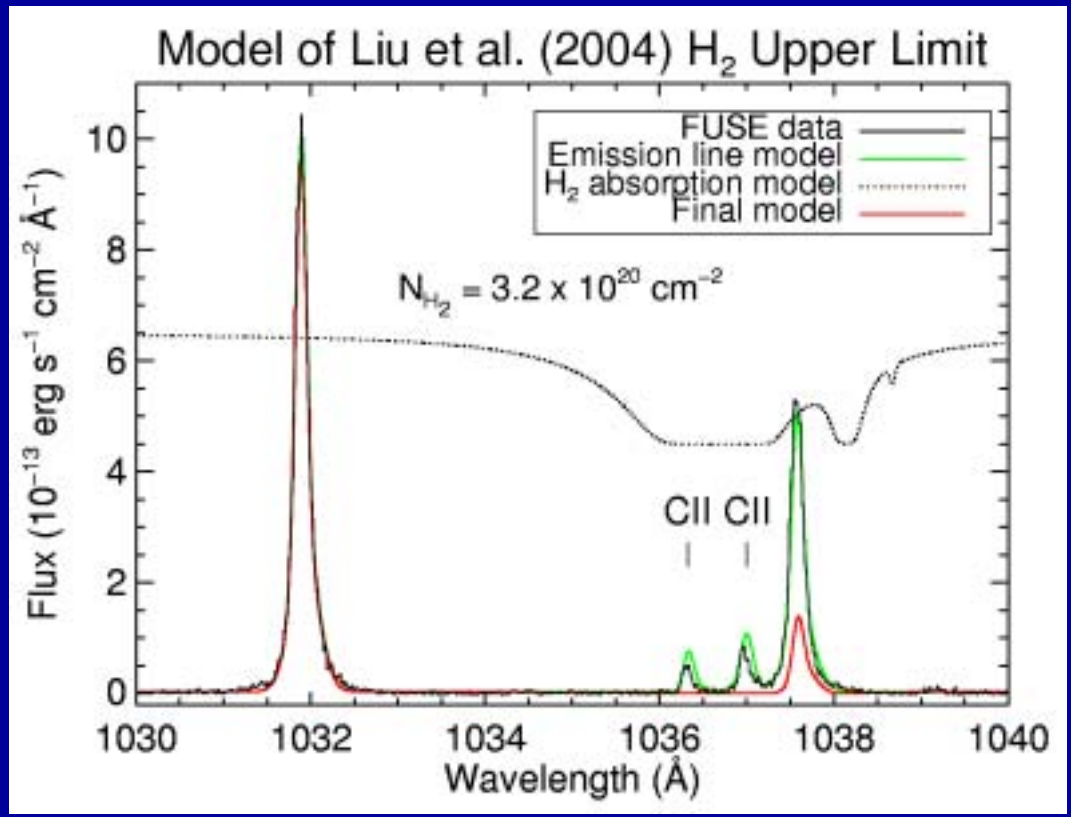
H_2 Limit from Sub-mm Observations

- Line-of-sight H_2 column density

  $< 3.2 \times 10^{20}$ cm^{-2}

  (Liu et al. 2004)

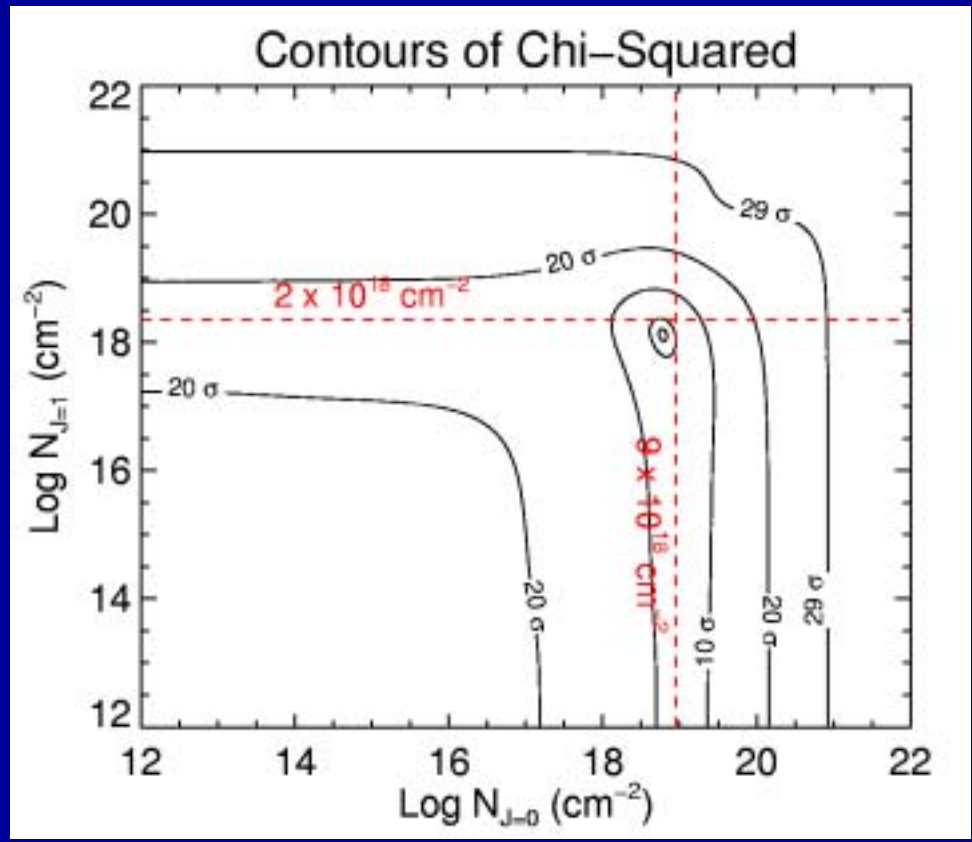
- $T_{H2} = T_{dust} = 40$ K
- Sub-mm upper limit ruled out at 32σ level



- Result is insensitive to assumed H_2 velocity

H_2 Limit from FUSE Observations

- H_2 model with N(J=0) and N(J=1)
- Set v_{H2} to stellar and ISM velocities
  - stellar velocity = expected CS gas velocity
- 3σ limits for $v_{H2} = v_{star}$:
  - $N(J=0) < 9 \times 10^{18}$ cm^{-2}
  - $N(J=1) < 2 \times 10^{18}$ cm^{-2}
  - Smaller limits for $v = v_{ISM}$



Total upper limit = 1×10^{19} cm^{-2}

Implications

Gas-to-Dust

- Sub-mm H_2 : $< 3.2 \times 10^{20}$ cm^{-2} $< 118 : 1$

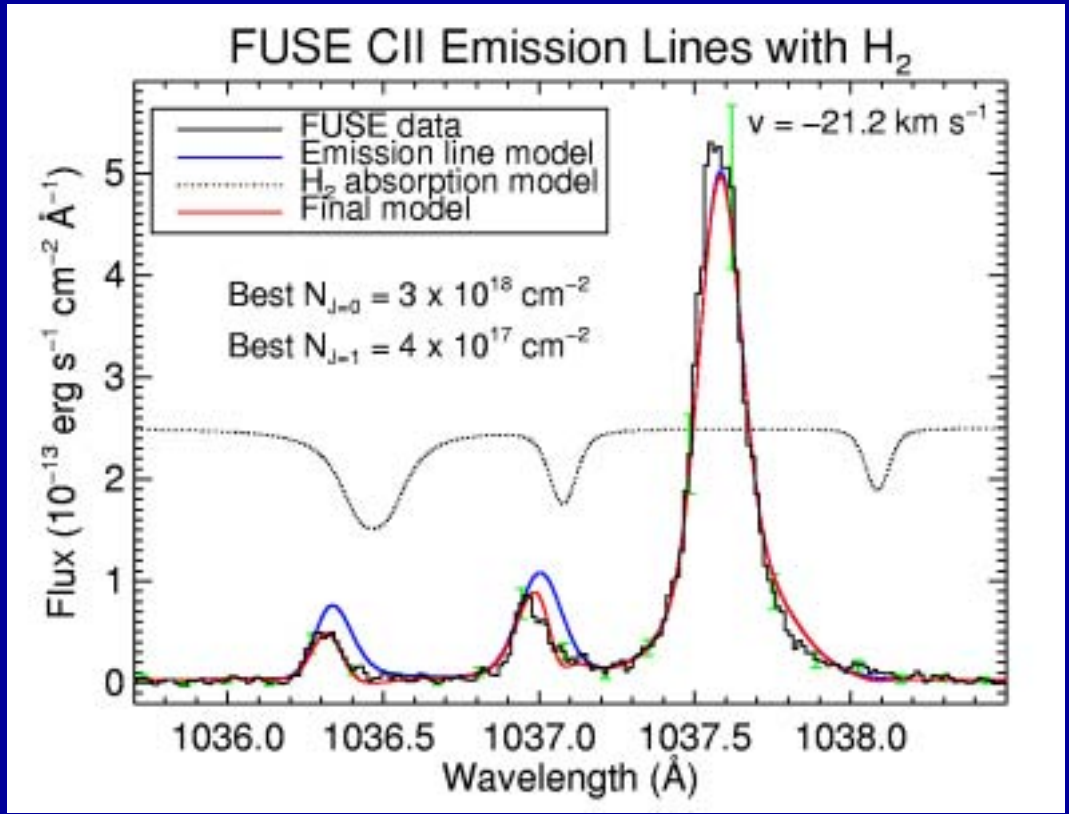
  Far-UV H_2 : $< 1 \times 10^{19}$ cm^{-2} $< 4 : 1$

	AU Mic	Beta Pic	ISM
Spec. Type	M1	A5	
L (L_{solar})	0.1	8.7	
M_{dust} ($M_\oplus$)	0.01 (Liu et al. 2004)	0.04 (Dent et al. 2000)	
M_{H2} / M_{dust}	< 4:1	< 3:1	100:1

Gas depletion not affected by spectral type ?

Future Work

- Intriguing discrepancy between data and model on red wings of CII lines
- Lines are too narrow
- Could be a hint of H_2 absorption (N_{H2} ~ few × 10^{18} cm^{-2})
- But could be at the velocity of the LISM



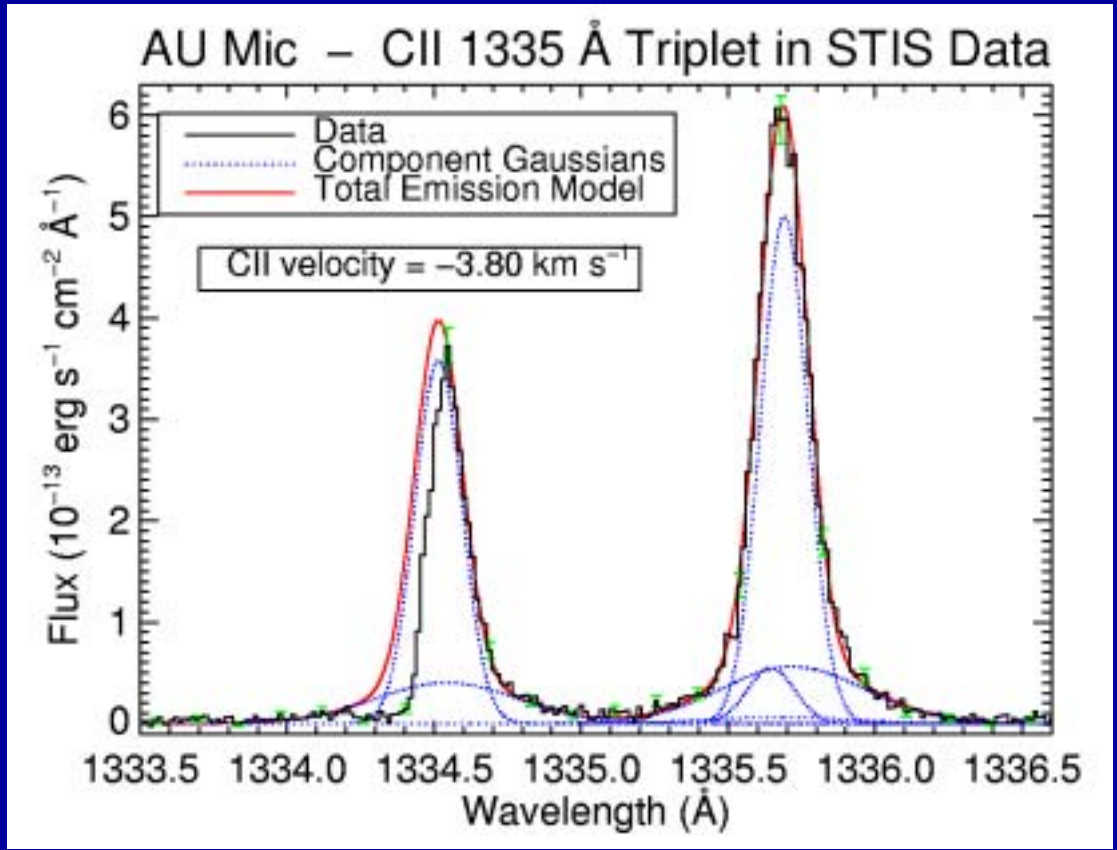
Investigate CII doublet model, characterize systematic errors

C II Model

- IS C II λ1334 absorption
- Modeled blended λ1335 line w/ narrow and broad Gaussians
- Used parameters to model λ1334 line.

v = – 3.8 km/s

v_{ϕ} = – 4.89 km/s



(Barrado y Navascués et al. 1999)

Interstellar CII